DOCUMENT RESUME

ED 412 085 SE 060 597

AUTHOR	Falk, Joni; Drayton, Brian
TITLE	Dynamics of the Relationships between Science Teachers and Scientists in an Innovative Mentorship Collaboration.
INSTITUTION	TERC, Cambridge, MA.
SPONS AGENCY	National Science Foundation, Arlington, VA.
PUB DATE	1997-00-00
NOTE	27p.; Paper presented at the Annual Meeting of the American Educational Research Association (Chicago, IL, March, 1997).
AVAILABLE FROM	TERC, 2067 Massachusetts Avenue, Cambridge, MA 02140.
PUB TYPE	Reports - Descriptive (141) -- Speeches/Meeting Papers (150)
EDRS PRICE	EDRS Price MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	*Cooperation; High Schools; Higher Education; Interprofessional Relationship; *Mentors; *Partnerships in Education; Professional Development; School Business Relationship; Science Education; *Science Teachers; *Scientists

ABSTRACT

This paper addresses the emerging relationship between teams of high school science teachers and ecologists who were paired in a year-long collaborative endeavor. The specific focus is on the benefits reported by the teachers and the ecologists participating in the Teacher Enhancement through Pedagogy and Ecology Project (TEPE). The teachers and ecologists agreed on the kinds of benefits exchanged but rank them differently in degree of importance. Although science content learning is an important value derived from this collaboration, more lasting impact on teachers' self-perceptions and practice seemed to derive from the experience of science practice and from the connection to the scientists' culture. The scientists benefit from teachers' engagement with their work in many ways including increased enthusiasm, research data, and a connection with the school environment. (AIM)

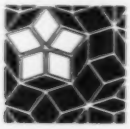
****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED 412 085

Dynamics of the Relationships Between Science Teachers and Scientists in an Innovative Mentorship Collaboration

by Joni Falk and Brian Drayton

TERC
2067 Massachusetts Avenue,
Cambridge MA 02140



TERC

PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL IN OTHER THAN PAPER COPY HAS BEEN GRANTED BY

J. Falk
B Drayton

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

Contact: Joni Falk (joni_falk@terc.edu)
or Brian Drayton (brian_drayton@terc.edu)

TERC
2067 Massachusetts Avenue,
Cambridge MA 02140

SE 061 917

BEST COPY AVAILABLE

Abstract

While many teacher enhancement projects involve interactions between scientists and teachers little has been documented about the dynamics of this relationship. The proposed paper addresses the emerging relationship between teams of high school science teachers and ecologists who were paired in a year long collaborative endeavor. The specific focus is on the benefits reported by the teachers and the ecologists participating in the Teacher Enhancement through Pedagogy and Ecology Project (TEPE), a three-year effort of TERC (Cambridge, MA) funded by the National Science Foundation. The teachers and ecologists agree on the kinds of benefits exchanged, but rank them differently in importance. Although science content learning is an important value derived from this collaboration, more lasting impact on teachers' self-perceptions and practice seem to derive from experience of science practice, and from the connection to the scientists' culture. The scientists benefit from teachers' engagement with their work in many different ways, including increased enthusiasm , research data, and a connection with the school environment.

Dynamics of the Relationships Between Science Teachers and Scientists in an Innovative Mentorship Collaboration

There are many current initiatives that promote the pairing of scientists with teachers (NRC 1996). Scientists are asked to act in different capacities including giving lectures, serving as mentors, and providing laboratory experiences. The scientist-classroom connection, however, seems fraught with difficulties and unrealized potential, as much as with promise and results (Berkowitz, 1997; Pennypacker 1997; Weir et al., 1990).

Most often, these endeavors are intended to bolster teachers' content knowledge by offering an "expert" to lend a guiding hand or to convey specific information. Yet, it is often not well articulated just how this knowledge will get transferred from scientist to teacher, or how this newly acquired knowledge will be incorporated by the teachers into their curriculum. Further, it is unclear what contribution this mixing of a teacher with a scientist contributes to the difficult task of transforming both content and pedagogical style within the classroom. The simple "transfer" of content knowledge cannot affect something so complex as teachers' practice on its own (Huberman 1995).

There is clearly an expectation that teachers will gain something from these relationships that goes beyond straight content knowledge that could be obtained from a textbook. It is often hoped that the scientist will share expertise not only about the specific content domain but about the "doing" of science, and in many instances that the scientist will also serve to inspire students as someone who is actively engaged in scientific discovery. (TERC & Concord Consortium, in press, NRC, 1996) However, there is a scarcity of research on what the teachers actually feel that they gain from this relationship, and even less research on how the scientist benefits from such a relationship (Feiman-Nemser, 1996). Further, there are significant logistical and cultural problems to be overcome in maintaining a long-term relationship between teachers and professionals from another sphere of work, however close the thematic connections may be between the two.

As a result, such associations have tended to take the form of relatively short-lived interactions, structured to make very efficient use of the time of both teacher and scientist. A very high proportion of the teacher-enhancement programs that connect teachers and scientists

take the form of short-term encounters such as workshops, consulting relationships, classroom visits, curriculum development sessions, or short-term internships. Of the 190 TE programs abstracted in the NRC's *The Role of Scientists in the Professional Development of Teachers* (1996), perhaps as many as 75% fall into this category.

Yet most studies of teacher change agree that, especially when the change being advocated is a complex one, time is a critical ingredient for success, both time for "input," such as the learning of a new technique, and time for digestion, i.e., understanding the implications of an innovation in terms of science and in terms of pedagogy (Fullan, 1991).

But what kinds of longer-term relationships can be formed between working scientists and teachers, and what can success look like in such a collaboration?

The following study investigates the benefits described by teachers and ecologists who were involved in a year-long collaborative institute in 1995–6. Teachers and ecologists described their emerging relationship with their ecologist during the first half of the year. At the end of the year, both teachers and ecologists were asked about the value and nature of the partnership. A more in depth understanding of the complex benefits of such a relationship emerged. The research questions which we address in this paper are:

- What percentage of teacher-scientist teams last throughout the year?
- What do the teachers say the ecologists contributed to this relationship?
- How do teachers report that they benefited from this relationship?
- What do ecologists say that they provided to this relationship?
- How did the ecologists benefit from this relationship?

Context

The project that provided the structure for the ecologist-teacher interactions we describe is called Teacher Enhancement in Pedagogy and Ecology, a three year teacher-enhancement grant, awarded in 1993 by the National Science Foundation to TERC in Cambridge MA.[1]

An underlying goal of the project was to encourage teachers to implement a more research oriented, inquiry based approach to the teaching of ecology at the high school level. It was the project's hypothesis that a shift towards inquiry would be facilitated by teachers' experiencing and engaging in open-ended research as adult learners, and by teachers' acquiring a greater depth of understanding about the domain of ecology. Thus, the emphasis was not on mastery of

[1] NSF/TE Grant 92-53280, Prassede Calabi, Principal Investigator.

a predetermined body of knowledge, but of engagement in research, with the science learning growing out of the investigation.

To this end teams of four teachers were paired with a local ecologist for a year-long collaborative effort during which the teachers engaged in conducting their own research, not necessarily including their students: the goal was for the teachers to have the opportunity to reengage with science as adult learners, not to provide the teachers with material to use in the classroom. The teachers were high school teachers, with the exception of four middle school teachers, each of whom joined a team of high school teachers. Although the majority of teachers taught life science subjects, other subjects ranged from mathematics and English to chemistry and physics. While some of the teachers would have the opportunity to teach ecology, others were interested to learn more about this science domain and about inquiry approaches which were generalizeable to their own field of teaching.

The project as implemented in the 1995–6 academic year involved 90 teachers in 24 teams, from Texas and Massachusetts. Each team collaborated with a local ecologist. The year-long teacher enhancement effort was marked by an initial two-week workshop and a fall and spring call-back weekend session. At the end of the summer institute, teacher teams designed a plan for an ongoing ecology research project which they would carry out during the year with the aid and support of their team ecologist. This project provided the framework for the Institute during most of the year.

Ecologists were recruited from universities (42%), state environmental agencies (42%), and private environmental groups or industry (16%). Teacher teams applying to the program often suggested the names of possible scientist collaborators. Each team ecologist needed to be in local proximity to the teacher teams. Application forms and subsequent phone interviews were used to explain the program as well as to select ecologists that were thought to be most appropriate. Specifically, we explained our focus on teacher-as-learner, and made clear that we were not asking the ecologists to act as fountains of facts. Rather we gave the analogy of a "coach;" each ecologist would need to negotiate their relationship with the teacher team. We sought ecologists that had some experience working with the public or with teachers. We shyed away from those who sounded too directive or dogmatic, and thus might not be comfortable with the learner-centered pedagogy of the project. Finally, we sought ecologists with a wide range of competencies, as well as an ability to communicate clearly.

While it was the expressed hope that the ecologists would provide scientific resources to teachers throughout the year it was not clear how these relationships would develop. TERC

staff provided some guidelines to the ecologists on effective ways to work with the team, and also feedback on the content and completeness of the plans being developed. The actual interactions were greatly influenced by the particular personalities and backgrounds of teachers and scientists. In addition, teams varied on how directive the ecologist was in suggesting a research question, whether or not teachers were involved in the ecologist's ongoing research how the teams viewed the importance of their findings, and to what degree the teachers' students would be involved[2].

Data Sources, Data Collection, and Analysis Methods

Data used for this study were gathered from July 1995 through April 1996 from teacher portfolios, teacher questionnaires, ecologist questionnaires, and from ecologist focus-group sessions which were audio-taped and transcribed.

Initial data were collected from journals kept by teachers during the summer workshop in 1995. Teachers were asked to extract journal entries that pertained to their relationship to their ecologist, and to add reflections on these entries. Eighty-nine of the ninety teachers wrote about how they thought the ecologist was contributing to their team. All responses were read and coded by two researchers. Five main themes emerged which identified areas of ecologist contributions. Portfolio entries allowed us to gain insight into recurrent themes but we did not calculate frequencies at this point since teachers were not responding to a direct question or query. Some teachers may not have thought to write on a particular theme but may in fact have agreed with others who wrote about it.

To understand how and if each of these themes played out for individuals, and to be able to calculate frequency of occurrance, we sent follow-up questionnaires to each teacher that specifically addressed the five themes most frequently mentioned in the portfolios. Teachers were asked to comment if, and in what ways, their ecologist provided each of the five areas of benefit that were derived from analysis of teacher portfolios. They were asked at the same time to code the two most important benefits that they received.

In order to compare the teachers' experience with the ecologists' experience of these partnerships, we sent the same follow-up questionnaire to the team ecologists asking them to discuss if, and in what ways they thought they had provided each of the five areas on benefit. In addition the ecologists were also asked to rate the two categories in which they thought their most important contribution had been made. Both the ecologist and teacher questionnires

---

[2] Drayton, B and J Falk. "Dimensions of teacher-scientist collaboration in an innovative teacher enhancement project." In preparation.

focused on what the ecologist had given to the teacher teams as opposed to how the ecologists may have benefitted from this relationship. Therefore at the end of the year two small focus groups were conducted with the ecologists who had replied to the questionnaire. The focus group sessions were taped and transcribed. Questions focused on what the ecologists had gained from these relationships. We received 70 returned teacher questionnaires (78% return rate) and 13 returned ecologist questionnaires (51% return rate); 13 ecologists participated in the focus groups.

Results

Longevity of Relationships

In our analysis of teachers' portfolio writings and of data collected as part of the project monitoring of team activities during 1995–6, we were able to ascertain that twenty out of twenty-four teacher teams reported positive relationships with their ecologist. We define a positive relationship as follows:

- The formal relationship lasted throughout the entire year where
- formal and informal meetings continued to happen, as well as that
- a collaborative research project was negotiated and carried through.

The duration of the relationships is of interest because both teachers and ecologists reported multiple impediments to long-term collaborations of this sort. Important among these are

- Some teachers said that their school provided limited time during the school year for teacher enhancement activities
- Some found a lack of support from school administration (despite written agreements arranged for at the beginning of the project)
- Some teachers suggested that there was no culture of teacher team collaboration at the school, which would provide institutional support such as planning time or space, or permission for innovations in classroom or teacher scheduling or content.
- Some teams reported a lack of clarity on the part of both teachers and ecologists about intiation of activities or team leadership: should the ecologist take the lead? If one or the other did not stay in contact, who should take responsibility to address the issue?

Four of the 24 teams had a negative teacher-ecologist relationship. In three cases the ecologist proved not accessible and the relationship unraveled during the course of the year. In one case the ecologist struck the team as too insistent on his own agenda, and the working relationship had to be renegotiated, with the ecologist essentially having no impact on the content or conduct of the teachers' project, but continuing to respond to occasional requests for equipment or references.

Of the twenty successful teams various models were employed by teachers and ecologists in sustaining their relationship. Some teams (60%) involved their students in their research with the ecologist while others did not (40%) Some teachers became involved in the ongoing research of the ecologist (25%) while other teachers pursued their own questions (75%). Many teams reported that initial expectations needed to be renegotiated. Realistic time constraints and commitments on the parts of both the ecologists and the teachers needed to be developed. A mutual sense of trust and respect between ecologists and teachers needed to be developed before fruitful relationships could procede.

Benefits to Teachers and Ecologists

From open-ended responses from 89 teacher journals, five major categories of benefit had emerged, which were used in the follow-up questionnaire. These categories were:

- Enthusiasm about Ecology
- Science Content and Process
- Ecologist as a Provider of Resources
- Ecologist Providing Continuing Support
- Modeling Pedagogical Approaches to the Teaching of Science

We then analyzed the 70 returned teacher questionnaires, and 13 returned ecologist questionnaires to see if and how these benefits played out for each individual and to what extent they were seen as important.

When we coded how teachers and ecologists ranked the two most important benefits, we found that teachers and ecologists rated the importance of each of the above contributions differently. Table 1 compares the teachers' and ecologists' rankings of the relative importance of these benefit categories.

In analyzing the questionnaire we noted that the meanings of each of these categories contained many rich variations. Sometimes teachers interpreted these categories differently from the ecologists. However, for both groups, a single word such as "enthusiasm" was used to describe different experiences. The questions thus elicited a range of meanings for the category labels which are useful in understanding the process of teacher-scientist collaboration.

1. Scientist Enthusiasm

Enthusiasm has often been construed as a collateral benefit of a scientist-teacher relationship, a benefit that is discussed second to the material, knowledge, and resources that the scientist shares. Our study, however, showed that this sense of enthusiasm was a primary

value, and essential in providing teachers with a renewed interest in inquiry in Ecology. Teachers overall, rated enthusiasm as the most important benefit that they derived. Out of 70 respondents, 65 teachers (92.9%) stated that enthusiasm was a factor in their relationship.

When teachers discussed this category , they did so in two different modes, and often the same teacher would mention both, putting one or another in the foreground. These two modes were:

- enthusiasm shown for the domain of ecology
- enthusiasm shown for the research and work of the teacher teams.

Thirty seven (52.9%) responses spoke of the importance of the ecologist sharing a love for their subject matter. They provided real-life applications of the science which made it seem exciting and engaging for the teachers.

> Our Ecologist(s) are active in their field of study. It was exciting to witness their work or discuss their work as they were actually involved. Great opportunity to study real research activities.

> This is a person who's life work is in the field and he obviously loves it. Because of his interest in several areas he would bring things up that we would not have thought of.

Thirty one respondents (44.3%) spoke of the importance of the enthusiasm that the ecologists shared about the teachers' research. In this regard, they were pointing out the need and the benefit derived from having a knowledgeable "cheerleader" to encourage, support and validate.

> She respected the fact that our group had different directions (within the group, individual interests, etc.) and she was willing to spread her enthusiasm and interest in whichever direction it was needed.

These two forms of enthusiasm were not mutually exclusive, and some responses incorporated both. An example of two such responses:

> For me the ecologist was the one person I wasn't and what I hoped to become. He brought with him a real desire to probe and find out various things we were interested in finding out. To use a chemical term, he was the catalyst.

> R. loves ecology. That shows! She was very supportive of what we were trying to do with our research in the classroom. She encouraged us to be excited.

Ecologist data confirmed that the ecologists recognized enthusiasm as an important part of their contribution, and in fact this sharing was important to them personally as well. Twelve of the 13 ecologist questionnaires (92.3%) affirmed that this was an important element for them. The ecologists' answers also confirmed the two kinds of enthusiasm that the teachers had described. Seven of the responses (53.9%) spoke of being enthusiastic about the teachers work and contributions, 53.9% spoke of sharing an enthusiasm for the domain of ecology. Again these two groups were not mutually exclusive, as is shown in the following two responses.

> What goes along with sharing one's enthusiasm, I think, is being able in some way to share an accessibility. That is, if you are able to make them feel at ease, and to relate to you as a person, it makes the subject matter less intimidating. That may sound a little hokey but I think it's especially important to someone who may have some degree of insecurity about their knowledge in a particular field. Sometimes even the least bit of pretentiousness is enough to turn somebody off to something that is already intimidating on its own. Anyway, I felt I was fortunate to get along well with my team and I think that helped a lot to allow me to share what I know with them and to give them some of the confidence that is important to fueling enthusiasm early on.

Another ecologist writes:

> My goal with my team has always been to encourage them and excite them about ecology. I tried to do that during our workshop last summer and while in the field on their campus by showing them field examples of all the things that ecology encompasses in the every day natural world around them, be it big or small. My feeling is that if my enthusiasm for ecology rubs off on them even in a small way, then they will be more confident and enthusiastic teachers of the subject.

Analysis of focus group transcripts reveals that transmission of enthusiasm is in fact not a one-way gift. Several ecologists mention that they benefited from the enthusiasm generated by the teachers. One ecologist says "Just their enthusiasm was wonderful. They're going to be these ambassadors for all this stuff." This ecologist had found a partner to spread his love of the subject matter to others. Other ecologists mentioned how meaningful it was for them to have the opportunity to see the enthusiasm that was sparked in the lives of the students. In this regard one ecologist commented:

> ...[T]here were three or four students who were very interested in pursuing Fish and Wildlife as a career...these three students were absolutely gung ho. To me that was good; that was a very positive thing, to have had a direct contact with one of these students.

Another ecologist similarly expresses the enjoyment of working with the teachers and the satisfaction of realizing that through the teachers he can influence the lives of students. He writes:

> I've enjoyed my teachers. I thoroughly enjoy the interactions with them, because it gives me a different perspective...I take the philosophy if I can encourage one out of 100 students to take up natural sciences I've accomplished something that's forever.

2. *Science Content and Process*

As might have been expected, the sharing of science content and process skills was recognized as an important benefit of the scientists' involvement. Of 70 respondents to this question, 63 (90%) responded that this was an important benefit. It was rated second to enthusiasm in degree of benefit received.

When teachers wrote about this category, their replies were split evenly between science content (44.3%) — such as insect ecology, restoration ecology, or bioindicators of water ecology — and science process (42.3%) such as the organizing of a study, or data analysis, or specific techniques. This was also not an either/or question and many teachers spoke of benefiting from both.

An example of a response pertaining to *content*:

> I never knew there was such a thing as a toothpick grasshopper, I had difficulty distinguishing a male from a female and had never observed "pulsating" malpighian tubules under a stereoscope. I had never thought about relative humidity controlling the activity of insects during the day and never thought I'd come to enjoy them as I do.

An example of process:

> Our ecologist knew a great deal about our project topic.... He was informative about the types of testing we were doing and provided training...on collection and testing, techniques.

Some of the other related areas that teachers identified included having the ecologist available as a resource as questions arose (22.9%), getting a deeper understanding on what some of the real world applications of techniques were (14.3%), and in receiving help in being able to draw conclusions from the research findings that they were acquiring (7.1%). Some examples of such responses are:

Real world applications:

> He was very informative — giving us information that you don't find in the text book. He told us about life cycles of mosquitoes and about his [related] research [that] he has done and his findings.

Helping draw conclusions:

> What was GREAT for me personally was when I made my own conclusions quietly to myself, but had the chance to check these conclusions with S. I really enjoyed having "my own" ecologist as a resource.

From the ecologists' perspective, 10 of the thirteen ecologists (76.9%) replied that they had provided either science content and/or science process skills. Of these ten affirmative responses, 69% mention process skills and 7 (53.8%) mention content. Much of the content and process was transmitted in informal situations. One ecologist said:

> G [a teacher] and I are working on two lab exercises that she will use with her students, the idea for their exercises came out of our walks at the workshop and at W. Roxbury. Each involves scientific methods of observation or hypothesis testing. My role was to provide idea for labs, locations for doing them and to critique drafts for science content and methods.

Of the three ecologists who did not reply affirmatively, one respondent did not respond to this question and the other two felt that they could only provide limited amounts of information as the teachers were not at a place where they could use more. One ecologist who was disappointed that the teachers on his team were not interested in working in his lab writes:

> At the outset of this "experiment" I was willing to welcome my team members into my lab and provide them with the opportunity to participate in a suitable collaborative project. The team of teachers were not interested in this approach. The team had a variety of reasons for not wanting to engage in this level of involvement. Our project involved minimal sciences info/process.

This was a case where ecologist and teacher had different expectations which needed to be renegotiated.

3. Ecologist as a Provider of Resources

Fifty eight out of 70 teacher respondents (82.9%) wrote that their ecologist was a provider of resources. We could not have anticipated the variety of interactions that teachers described under resources.

The resources that teachers mentioned were, equipment and materials (55.7%), sources for acquiring equipment (10%), logistical help in conducting research(5.7%), support and brainstorming (8.6%), contacts with others (28.6%), funds (7%), help in writing proposals(7%), leverage in getting organizations and foundations interested in contributing to the project (7%), and exposure to a different professional culture(10%). As in other categories some respondents mentioned more than one type.

Teacher responses showed that there were four different forms of benefit that were derived from the above resources.

The first is I. This may have come in the form of computer equipment, laboratory equipment, software, books, fish, pet food, or funds. Some of the equipment was actually given to the schools by universities, organizations, and foundations as a result of the ecologists interventions while as other equipment was given to the teachers as a loan.

> M. has provided H. and myself with Pentium computers, which we have used since Nov 95.

> L. has contacted various organizations and companies for materials and moneys on our behalf. She secured a $850 gift from one company for the xeroscape.

The second benefit was that the teachers gained a greater capacity to know *how to acquire* equipment, funds and support for such work in the future. This was accomplished by the ecologist sharing sources for equipment, as well as contacts. There were several instances where the ecologist mentored teachers in writing proposals for additional funding.

> Through San Anotonio Water systems we received a grant for 2500 which R. [the ecologist] helped us to write, to purchase all our field equipment. She gave us contacts at TNRCC, Texas Watch, etx. to help us gather a lot of our information.

The third benefit relates to resources that simplified and organized the actual *doing of research*. In some cases this meant providing logistical help, in other cases this meant being available as a resource to problem shoot or to brainstorm with.

> D. did an excellent job of coordinating the logistics of gathering people, equipment, and other resources for our data collection. He also funded the bulk of our trip expenses which eased the pressure on us when bringing our students.

> I truly fell that if we needed directions or answers to questions that D. would be very willing to help. I would not hesitate to call him.

The fourth benefit was that the ecologists provided a bridge for the teachers to reach beyond the classroom walls and to *experience the culture of the scientific community*. Through the ecologists contacts teachers met with professors and other scientists shared an interest in the research that the teachers were conducting. Teachers experienced something of the professional network within which scientists work. Several teams visited the ecologists fieldsites and labs and had exposure first hand to the equipment, and research that was taking place.

> We toured Sam Houston State University Campus. We were introduced to assorted ecologists and research personnel. He took us to TRIES (Texas Regional Institute of Ecological Studies) and had lab techs' show us all the current computer equipment and monitoring equipment for the state.

> She invited our group into UMass to use a higher resolution microscope, T.V. monitor, and whatever other equipment we needed. This was fun and very educational. I can see how my students would benefit by a monitor attached to a scope. I would like to use S. to figure out how I can bring more technology into my classroom.

It appears that the ecologists were often unaware of the resources that they were providing to the teams. When asked if they had provided resources only 7 of the 13 (54%) thought that they had. These seven responses included mention of equipment (30.8%) help with proposal writing and obtaining funds (15.4%) giving sources for equipment (15.4%) and providing contacts with others (7.7%).

Six ecologists (46%) indicated that they did not provide resources. It is interesting that in all six cases their teacher team members felt that the ecologists *did* provide resources. Analysis of these teams shows that the resources that the teachers received were primarily logistical help, reference material, introductions to contacts that were helpful, and exposure to the culture and facilities of scientists. It is possible that these ecologists were thinking in terms of equipment rather than less tangible items such as exposing teachers to their labs and introducing them to colleagues. Yet, for the teachers, these less tangible benefits were important and appreciated.

Just as the ecologists were a resource for teachers to reach outside of their culture to the scientific community, the teachers provided a way for ecologists to have a greater insight into the classroom. In the ecologist focus group, one ecologist said

> It actually had applications. I could understand what students and people at that level are being taught and it helped me better understand how I should convey information in the outreach work I do.

Similarly another ecologist stated

> I do a lot of public stuff in my job, and I deal at all levels of the public. And it helped me better understand what's going on in the classroom. And it gives me another perspective.

4. *Ecologist Providing Continuing Support*

Fifty nine out of the 70 (84.3%) respondents wrote that the ecologist was a source of continuing support for their work. The range of comments on this category extended our understanding of what it means for a teacher to be supported. Teachers' responses showed the importance of developing a collegial, trusting relationship between teacher and scientist. As the scientist becomes interested in classroom applications, the scientist shares the teachers' work, reciprocating respect with respect.

Teachers' rich descriptions of what it meant for the scientist to be a source of support included: being available as a resource as questions arose and for brainstorming (34.3%), to help generate new ideas and future directions (27.1%), to help think about classroom applications (14.3%), to validate and encourage the teachers' research and efforts (10%), and to facilitate the workings of the teacher teams (10%). Many responses included several of the above mentioned elements.

Having a relationship with an ecologist provided teachers with a person with whom to have an interactive, sustained conversation about how they would either proceed with their research or how they would introduce some new content or technique into their classroom. Having an interested outsider to brainstorm with, and ask questions of, was essential for many teachers (28.6%). But, in addition 19 respondents (27.1%) felt that the ecologist was pivotal in generating new ideas, in moving them a step forward, in introducing them to concepts or approaches that they may not have stumbled on their own.

> ...We hadn't thought of safety concerns like snake bites in the creek and other practical concerns that she deals with everyday

> M. suggested comparing tree bud development on the sun facing vs. North facing slope of the hill. I would never have thought of this as a March-April project.

> He suggested several places to go to do our ecology work.... He knows the areas well.

Ten respondents (14.3%) wrote of how the ecologists support led to changes that were implemented in the classroom. Some examples are:

> We compared labs, on a couple of occasions even joining the Williams Colllege class with our H.S. sophomores, in the field.

> During our meetings I, and other members of our group, have asked and discussed methods of incorporating our research in our classes.

Seven respondents (10%) spoke of a support function that we have labeled validating. These responses were characterized by teachers wanting to check in with someone that they were on track and that their work was of value.

> DT is always the first person we go to with ideas. He is always supportive and helps you to feel your idea is important.

Last, seven respondents reported that the ecologists were important as a facilitator for the teacher teams. They were a catalyst for teachers to meet, a facilitator for teachers to reflect, and reach decision points, and an impartial arbitrator when disagreements arose.

> At the summer workshop she helped people talk things through and brainstorm through to clarity.

> Our ecologist was excellent at helping the group come up with plans, possible strategies, as a time line. She took over a leadership role at times, like an impartial mediator, when we needed to finalize decisions, etc. But it was done in a very positive way.

Analysis of the ecologists' questionnaires showed that eleven of the 13 responding ecologists (84.6%) wrote that they were a part of the teachers' support system. These eleven mentioned providing functions of brainstorming (61.5%), generating new ideas (15.3%) and discussing classroom applications (30.6%). None of the ecologists reported being aware that they served a role in validating for the teachers the importance of the their ideas or that they had facilitated the workings of the teacher teams.

The ecologists not only gave to this relationship but clearly profited from it as well. In the ecologist focus group, ecologists stated how they had enjoyed having a sustained relationship which was unfolding over time. One ecologist expresses how this relationship was different from past ecologist -teacher experiences:

> It was also good for me to be able to see how teachers looked at students because most of our interactions with students is that we go somewhere and we make a twenty minute presentation...or whatever. but, we never really have the opportunity to work on a long term basis with students...on a project, and that was good for me to see how students behave, and perceptions....

Several ecologists stated during the focus group their intention to continue the relationship for the indefinite future, even though their contract with us was at an end. This decision to stay involved despite no future support clearly indicates that the relationship had become important to the scientist as well as to the teachers. One ecologist speaks about his view of a long term relationship:

> The fact the we've made much slower progress than one might have expected, both myself and them, that has been a consequence of both my being over worked and their being overworked. They...are very committed to their students and...bombarded from every direction by student needs and its not easy to make time for something like this.... So I see this relationship continuing to develop over a long time.... The essential thing we have accomplished is developing a basis for a relationship that can continue as long as they're willing to seek me out and I'm willing to make my time free. And I think those two things will continue.

5. Modeling Pedagogical Approaches to the Teaching of Science

This area of benefit was the most controversial among participants. Thirty-one (44.9%) teachers responded that this was a contribution of their ecologist. This query was interpreted in

two different ways by respondents. Twenty-one(30%) of those who responded affirmatively mentioned that their ecologist modeled pedagogical approaches such as open ended inquiry, or an approach to eliciting student questions. Ten respondents wrote of specific ecological techniques such as transecting, identification techniques, etc.

Some examples of those who wrote that the ecologist modeled general pedagogical techniques were:

> He modeled his approach to learning, his use of hands-on approach to learning.
>
> ---
>
> She let us discover on our own, in this way she modeled teaching behavior...
>
> ---
>
> He asked a lot of leading questions but did not lead us directly to the answers.
>
> ---
>
> J. always modeled open ended questioning patterns and positive reinforcement.

In contrast, those who wrote of specific techniques wrote:

> Sample by transect — counting unknown plant frequency — everyone pick a leaf then find frequency on south of North side of building.
>
> I have not yet taken back DL's ideas. They are with H_20 quality studies and I'm waiting for warmer conditions.

It is perhaps at least equally interesting to ponder the 39 (55.7%) questionnaires that did not mention this as an ecologist contribution. Despite the fact that the ecologists were integrally related in teams doing open ended inquiry, research into ecology, and field studies, the majority of participants felt that pedagogy was not an important element in the teacher-scientist relationship. While many of these respondents simply wrote "did not apply" some respondents elucidated why they thought this did not happen. One respondent writes:

> I'm not sure that this area applies to our relationship with our ecologist. Our focus was on development of teacher background and knowledge base, not on its application in our teaching methods.

Indeed the project did encourage teachers to spend the year experimenting and conducting research with other teachers instead of feeling pressured to learn something one day in order to implement in the classroom the next. We found that despite this freedom most of the teachers

experimented with some element of what they were doing with their classrooms, but not all teams did.

Other teachers expressed that pedagogy was not an expectation that they had from the ecologist and therefore did not seek it regardless of whether or not the ecologist could have provided it. One respondent writes:

> Haven't made use of him in this way yet although I have no doubt that he could help us with approaches to teaching.

Other teachers viewed the ecologists as experts on content and science process but felt that pedagogy was the expertise of the teachers. In fact, some teachers wrote that they did not think the ecologist understood the pedagogical needs of their students. One teacher writes:

> ...I believe he is used to working with graduate students (slave labor) who just collect for him. We wanted our students to learn, so we tailored the project to our student needs.

From the ecologists' perspective eight of the thirteen (61.6%) wrote that they felt that they had modeled pedagogical approaches. These responses were divided into those who felt they did so by modeling specific scientific methods (30.8%) those that modeled inquiry (15.4%) and those who discussed pedagogical issues with the teachers (15.4%). Some ecologists felt that they met with some resistance when introducing new scientific approaches that might take more time within the classroom. One ecologist writes:

> After our study/field days the teachers took students to the same study sites and taught them about the river ecology. I tried to teach them standard scientific method, however, I did meet with some opposition to doing, for example, replication because it increased the work, but they are starting to do it.

Some ecologists mentioned that they thought teachers were already using inquiry approaches and one ecologist expressed a sentiment that was shared by some teachers when he wrote "My teachers seem to know how to deal with teaching a lot better than I can."

Discussion

Scientists and science teachers stand in a complex relationship. On the one hand, the science teacher is a major force in the nurture of new scientists, and of public understanding of, and support for, science and scientists (Fedock et al. 1996; Norris 1995). On the other hand, scientists can be said to produce the science teacher's official stock in trade, science knowledge, and because of their specialized training and their status in society they occupy a place of authority. The commonest model of the relation between the production and the teaching of

scientists might be stated as "the scientist creates knowledge, the teacher recreates or reports it."

This somewhat hierarchical schema contributes to the sense of inadequacy that many science teachers express with respect to their command of their subject field, and can tend to reinforce also a tendency to rely on more static, text-based science teaching, which is generally agreed to be unsatisfactory in principle (e.g., AAAS Frameworks), but is familiar and straightforward in its pedagogy.

The intention to change towards a pedagogy that is more open and inquiry-oriented presents several challenges to teachers, both conceptual and emotional, which seem to be most intense for teachers who have a clear separation in their mind between the doing and the teaching of science (Ruopp, et al. 1993; Simon & Jones 1991). There is a gap to be bridged.

It is our experience that this gap can be bridged intellectually and emotionally by an increased familiarity with science as actually practiced. To see how hard it is to get data, how complex and interpretive is the process of data analysis, and how personal and interactive is the process of inquiry in the scientific community, is to be able to put oneself in a concrete and vivid way in a continuum from those who concentrate primarily on the creation of new knowledge, the scientists, to those who are just learning this way of knowing and some of its findings, the students. The teachers then occupy a dynamic point in between these "extremes," if they can be called so.

Our study suggests that, when teachers make this conceptual shift from consumer of science to participant in it, they cannot make that leap merely on the basis of more science knowledge alone (Shulman, 1987). A partnership with a scientist provides important values which enable the teacher to incorporate live science into his or her own work, and make it more available to students. It is this important shift in the concreteness with which teachers understand the doing of science, and the sense of identification with it, that are reflected in the teachers' writing about their collaboration with ecologists on this project.

The work with the ecologists stimulated the teachers' engagement with science content. This was particularly effective because it was accompanied, not by specific curriculum, but by concrete behavior, cultural and conceptual tools that the teachers could then turn to use in their practice. Thus, we see these teachers learning science practice and applying their deeper understandings to their teaching in an interactive, empirical, and often critical fashion. This is reminiscent of Huberman's description of the teacher as *bricoleur*, a tinkerer, whose learning is often like that of an artisan (Huberman, 1993). The unsystematic nature of the collaborations

with the ecologists gave the teachers freedom to see and take what seemed of value at a particular point in their own thinking and change process (see Gunstone & Northfield, 1994 on teacher metacognition).

The unusual feature of this program, however, was that, unlike Huberman's community of teacher-artisans peers, these teams included at varying degrees of intensity a scientist, who is embedded in her or his own peer-community. Thus the teams in this project constituted a fruitful overlapping of two peer groups who developed the meaning of this collaboration over the course of time. The teachers were left with the important sense that this was a kind of overlap that they could create for themselves at need, and for the long term.

The majority of these teams withstood the test of time and were viewed as positive relationships. Sometimes expectations (such as how much science or time would be devoted) had to be renegotiated. Also teachers were sometimes wary that the scientists would respect them and a sense of trust needed to be developed. Some teachers expressed initial skepticism that such a relationship could work. They were doubtful that ecologists would have the time or interest to work teachers. Although most relationships started off well, some teams felt that they were not respected for their own scientific backgrounds. In these teams a sense of mutual respect needed to be built before a collaborative effort could take place.

From both the perspective of the ecologists and the teachers "enthusiasm" was the most important benefit value of the relationship. It was what made both sides feel good about staying in the relationship. This enthusiasm may have helped to reassure teachers that were wary of the scientists and also gave the scientist something immediate to offer.

It is easy to forget that teachers who teach others every day, need to stop and receive some nourishment and inspiration. Many teachers expressed how long it had been since they were students, since they had had an opportunity to reengage with science at their own level (as opposed to their students' level). For them, the enthusiasm that many of the ecologists brought for this field, rekindled teachers' love of science. Approximately half of our teams were interdisciplinary, some including teachers of social sciences or humanities, and these teachers expressed the same sense of encouragement and excitement, which carried over into their own areas of specialization.

Hargreaves (1995) points out that "desire" and similiar kinds of personal, affective engagement are critical to teachers' growth and sense of value in their work, and play an important role in maintaining a sense of dynamism and creativity in a teacher's career. Huberman (1995) suggests that those teachers who express most clearly a sense of satisfaction

in their work over the long term are those that take risks, extend their repertoire of pedagogical and content knowledge and expertise, and stay engaged with a varied group of professional associates, both within the schools and outside them.

With only one exception, the ecologists participating in this study felt that this element of enthusiasm was important for them as well. The teachers' interest in the ecologists' work, and the challenge of advising the teachers on their own projects, was stimulating to the ecologists, and produced learning and a renewal of engagement with their own work. In addition, seeing that this inspired enthusiasm and excitement in the teachers' students was rewarding, as it "let them see how their work lived in the real world."

Besides providing content and process teachers found a need to have a resource available as questions arose, to have someone show real life applications that they would not see in a book and to show how these applications played out in the surrounds near the school, and to help teachers make sense of the data that they were getting. Again, seeing the science enacted provided important information not available in other learning modes.

The use of a research project as the context for the teacher-scientist partnership brought out some kinds of conflict or tension that can be seen in this relationship. For example, in some cases the ecologists had higher expectations of the amount of content and process that the teachers would want than actually played out. Although many teams reported to us about the need to renegotiate their expectations with the ecologists, in at least two cases it was not possible for them to work this out to mutual satisfaction. Both teachers and ecologists then chose to interact in ways that were less demanding.

The ecologists were engaged with the question of their relationship to the educational community and to the community at large. The need to articulate or demonstrate their skills for "apprentices" pushed them in many cases to evaluate their habitual tools, in order to articulate their value. In addition, in several cases research data from the projects were of value to the ecologists' own work.

Resources proved to be far richer from the teachers' perspective than we would have imagined. Less tangible resources such as introduction to the culture of the scientist and also making contacts with others who were interested in the teachers research were recognized and appreciated by the teachers even though the scientists did not make note or seem to recognize the value of these contributions. Ecologists rated this contribution as relatively less important than the teachers did. One can surmise that the support systems that working scientists assume as part of their working world are not as apparent to them as to the teachers, who in this case

were "visitors from another culture." The access to institutional resources, the habits of fund-raising, and the collegiality (in particular the many ways of collaboration) normally part of a scientist's working conditions are not so universal in the typical teachers' world.

Thus the resources not only provided materials to the school but built capacity in the teachers to write proposals, to know how and where to get equipment and support.

Teachers experienced something of the professional network within which scientists work; some got to see and use working laboratories; some were helped in the writing of proposals for funds for school projects. All these provided a real enhancement of the teachers' professional skills. This kind of sharing of the tools and attitudes that make science research possible is a primary benefit of the sort of "apprenticeship" relationship that obtained here.

A critical feature of the teachers' enhanced sense of effectiveness or competence had to do with their connection, through their ecologist, with the science culture within which the ecologist moved. This provided the sense of increased security that comes from having deeper resources to call upon, but was coupled with the teachers' sense, provided in part by their own increased competence, but first and foremost by their ecologists' attitudes, that this was a culture to which they could connect, or even belong, something that came as a surprise to many who had not engaged in research before.

The partnership between teacher and scientist was viewed as a way of building bridges between the classroom and the outside, making teachers feel less isolated and more a part of the scientific community, and making ecologists more connected to the world outside their laboratories. This bridge-building was seen as important reason for the ecologists' involvement with the project in the first place. In a few cases, such work with the community was part of the scientists' daily mandate, especially those who worked for state or municipal agencies. For others, the project made possible a kind of "community service" that the ecologist saw as desirable, but had not found a way to do. The collaboration with schools provided a chance to have an impact on a "real world" that they did not usually visit, real children and teachers in a real school setting.

In addition to tangible "resources," the relationships provided teachers with several forms of support including brainstorming, generating new ideas, helping with classroom applications, being a facilitator for the teacher teams to work together and negotiate decisions, and helping to validate teachers ideas. The last two were not recognized by the ecologists but were nevertheless appreciated by the teachers as important contributions.

Ecologists considered their modeling of pedagogical approaches to be more important in the partnership than the teachers did. There was most agreement about the value of ecologists' modeling specific data collection techniques. However, there were a significant group of teachers who felt that they brought more expertise in modeling pedagogy than the ecologists and that this was not what they were expecting to receive from the ecologist. The relationship between science expertise and science pedagogy is one that deserves more exploration, and this kind of partnership could be a fruitful context in which to do it.

A sustained scientist-teacher relationship, if executed with care, can be a forceful factor in promoting teacher change, as well being a beneficial experience for the scientists involved. The teachers benefit from increased content knowledge and access to a wide range of professional resources, gaining a broader view of their professional identity. Such a relationship also provides teachers with a context for metacognition about themselves as learners and practitioners of science. Although it is often assumed that more science knowledge will support change, that is only partly the case. We see from our participants something more: that knowledge which is divorced from ways of enacting it is inert. Sharing in the creation of new ecological knowledge, and making new connections between the classroom and the world of science was liberating to the teachers, and motivated many of them to seek more content knowledge and reflect on how to introduce more inquiry into the classroom.

References

Berkowitz, A. (1997). A simple framework for considering the benefits of student-scientist partnerships. In TERC and Concord Consortium, (1997). National Conference on Student & Scientist Partnerships: Conference Report. Cambridge, MA: TERC.

Berkowitz, A. (1993) Ecology education in the United States. In Hale, Monica (Ed.) *Ecology in Education*. Cambridge: Cambridge University Press. Pp. 45–59.

Fedock, Patricia M, Ron Zambo, & William W. Cobern. (1996). The professional development of college science professors as science teacher educators. *Science Education*, 80(1): 5–19.

Fullan, M. (1991). *The new meaning of educational change*. New York: Teachers College Press.

Gunstone, Richard F. & Jeff Northfield. (1994). Metacognition and learning to teach. *International Journal of Science Education*, 16(5):523–37.

Hargreaves, Andy (1995) Development and desire: a post-modern perspective. In Guskey, T.R. and M. Huberman (eds) *Professional Development in Education: New paradigms and practices.* New York: Teachers College Press. pp. 9-34.

Herwitz, Stanley R. & Marion Guerra. (1996). Perspectives, partnerships, and values in science education: A university and public elementary school collaboration. *Science Education*, 80(1): 21–34.

Huberman, Michael (1995) Professional careers and professional development: Some intersections. In Guskey, T.R. and M. Huberman (eds) *Professional Development in Education: New paradigms and practices.* New York: Teachers College Press. pp. 193-224.

Huberman, Michael. (1993). The model of the independent artisan in teachers' professional relations. in Little, Judith Warren, Milbrey Wallin McLaughlin (eds). *Teachers' work: Individuals, colleagues, contexts.* New York: Teachers College Press.

National Research Council (NRC). (1996). *The role of scientists in the professional development of science teachers*. Washington: National Academy Press.

Norris, Stephen P. (1995). Learning to live with scientific expertise: Toward a theory of intellectual communalism for guiding science teaching. *Science Education*, 79(2):201–217.

Pennypacker, C. (1997. Why do scientists want teachers and students to do real research? In TERC & Concord Consortium, *National Conference on Student & Scientist Partnerships: Conference Report*. Cambridge, MA: TERC.

Ruopp, R., S. Gal, B. Drayton, & M. Pfister. (1993). *Labnet: Toward a community of practice*. Hillsdale, NJ: Lawrance Erlbaum Associates, Publishers.

Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, 57(1):1–22.

Simon, S. A. & A. T. Jones. (1992). *Open work in science: A review of existing practice*. Center for Educational Studies, King's College, University of London.

TERC & Concord Consortium. (1997). *National Conference on Student and Scientist Partnerships: Conference Report*. Cambridge, MA: TERC.

Weir, S., L. Krensky, & S. Gal. (1990). *Evaluation of the Star Schools project: Final report*. Cambridge, MA: TERC.

Table 1. Ranking of relative importance of ecologists' contributions by teachers and ecologists

	Teachers	Ecologists
1.	Enthusiasm about Ecology	Enthusiasm about Ecology
2.	Science Content and Process	Ecologist Providing Continuing Support
3.	Ecologist as a Provider of Resources	Modeling Pedagogical Approaches to the teaching of science
4.	Ecologist Providing Continuing Support	Science Content and Process
5.	Modeling Pedagogical Approaches to the teaching of science	Ecologist as a Provider of Resources